

Physical Science

Quarter 1 – Module 6:

Effects of Intermolecular Forces on Properties of Substances



Physical Science
Alternative Delivery Mode
Quarter 1 – Module 6: Effects of Intermolecular Forces on Properties of Substances
First Edition, 2020

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Introductory Message

For the facilitator:

Welcome to the Physical Science 11/12 Alternative Delivery Mode (ADM) Module on Effects of Intermolecular Forces on Properties of Substances!

This module was collaboratively designed, developed and reviewed by educators both from public and private institutions to assist you, the teacher or facilitator in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners into guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st century skills while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:



Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator, you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their own learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the Physical Science 11/12 Alternative Delivery Mode (ADM) Module on Effects of Intermolecular Forces on Properties of Substances!

The hand is one of the most symbolic parts of the human body. It is often used to depict skill, action and purpose. Through our hands we may learn, create and accomplish. Hence, the hand in this learning resource signifies that as a learner, you are capable and empowered to learn by yourself. Relevant competencies and skills can be successfully achieved at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be enabled to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:



What I Need to Know

This will give you an idea of the skills or competencies you are expected to learn in the module.



What I Know

This part includes an activity that aims to check what you already know about the lesson to take. If you get all the answers correctly (100%), you may decide to skip this module.



What's In

This is a brief drill or review to help you link the current lesson with the previous one.



What's New

In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity or a situation.



What is It

This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.



What's More

This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.



What I Have Learned

This includes questions or blank sentence/paragraph to be filled in to process what you learned from the lesson.



What I Can Do

This section provides an activity which will help you transfer your new knowledge or skill into real life situations or concerns.



Assessment

This is a task which aims to evaluate your level of mastery in achieving the learning competency.



Additional Activities

In this portion, another activity will be given to you to enrich your knowledge or skill of the lesson learned. This also tends retention of learned concepts.



Answer Key

This contains answers to all activities in the module.

At the end of this module you will also find:

References

This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain deep understanding of the relevant competencies. You can do it!

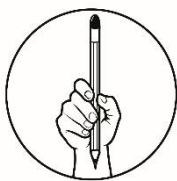


What I Need to Know

This module was designed and written with you in mind. It is here to help you master the *Effects of Intermolecular Forces on the Properties of Substances*. The scope of this module permits it to be used in different learning situations. The language used recognizes the varied vocabulary levels of students. The lessons are arranged to follow the standard sequence of the course. But the order in which you read them can be changed to correspond with the textbook you are now using.

After going through this module, you are expected to:

1. Identify the intermolecular forces present in each of the given substances.
2. Compare the strengths of intermolecular forces in pairs of substances.
3. Predict which among the given substances will exhibit higher boiling, melting, and freezing points, viscosity, surface tension, and solubilities.
4. Explain the effects of intermolecular forces on the properties of substances.



What I Know

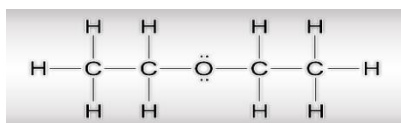
Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Liquids can form spherical elastic film to minimize surface area. What intermolecular forces are responsible for the formation of this film in water?
 - a. H-bonding
 - b. ion-induced dipole
 - c. dipole-induced dipole
 - d. London dispersion forces
2. The amount of energy required to stretch or increase the surface of a liquid by a unit area (ex., 1 cm²)
 - a. specific heat
 - b. surface tension
 - c. vapour pressure
 - d. heat of vaporization
3. The ability of water molecules to move against gravity
 - a. viscosity
 - b. temperature
 - c. surface tension
 - d. capillary action
4. Substances like heavy syrup and molasses flow slowly than water. The ability of these substances to resist flow is known as
 - a. Viscosity
 - b. Pressure
 - c. surface tension
 - d. capillary action
5. The pressure exerted by the vapor from the evaporation of a liquid or solid above a sample of the liquid or solid in a closed container
 - a. boiling point
 - b. capillary action
 - c. surface tension
 - d. vapour pressure

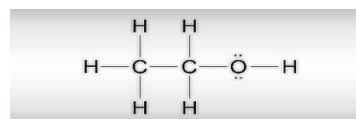
6. What is true about liquids with strong intermolecular forces?
- Vapour pressure is low.
 - Vapour pressure is high.
 - Viscosity tends to be low.
 - Viscosity is immeasurable.
7. This happens when the vapour pressure of a liquid becomes equal to the atmospheric pressure
- boiling
 - melting
freezing
 - condensing
8. Using the chart on the vapour pressure of the four substances, which among them has the lowest boiling point?

Substance	Vapour Pressure @ 25°C, atm
Diethyl ether (C ₂ H ₅) ₂ O	0.7
Bromine (Br ₂)	0.3
Ethyl alcohol (C ₂ H ₅ OH)	0.08
Water (H ₂ O)	0.03

- water
 - bromine
 - ethyl alcohol
 - diethyl ether
9. Based on the LEDES below, which has a lower boiling point and what accounts for the difference based on the intermolecular forces present in each species?



Diethyl ether

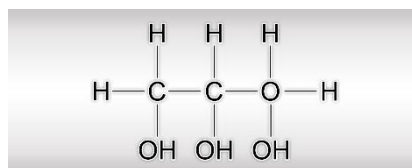


Ethyl alcohol

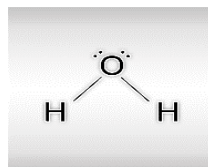
- Ethyl alcohol has a lower boiling point due to the dispersion forces present among the molecules.
- Ethyl alcohol has a higher boiling point because of the predominant H-bonding present among the molecules.
- Diethyl ether has a lower boiling point due to dipole-dipole interaction.
- Diethyl ether has a higher boiling point because it is capable of forming H-bond.

10. The atmospheric pressure on top of a mountain is lower than at sea level. As a consequence, what will happen to the cooking time of an egg on top of the mountain?
- The egg will cook faster since the boiling temperature will be lower.
 - The egg will cook at a shorter time since the boiling temperature will be higher.
 - The egg will cook at a longer time due to a lower boiling temperature.
 - The egg will cook at a shorter time due to higher boiling temperature.
11. Sodium chloride is completely soluble in water. What is responsible for its solubility in water?
- London dispersion forces in NaCl predominate leading to strong dipole interactions with water.
 - The presence of charged ends in NaCl enables dipole-dipole interaction with water.
 - The ions in NaCl participate in ion-induced dipole attractions with water.
 - Na^+ and Cl^- ions are favorable sites for H-bonding to form.
12. Xenon has a greater atomic weight than neon. Xe has 131.3 amu while Ne has 20.2 amu. The boiling points are 166.1K and 27.3K, respectively. How do intermolecular forces account for the difference?
- Dipole- dipole interaction is greater in Xe than Ne so more energy is needed to break the bonds.
 - H-bonding is greater for substances with higher atomic weight so greater energy is needed to change Xe to vapour.
 - Atomic weight increases the chance of lesser dispersion forces so greater energy is needed to separate Xe atoms to change to vapour
 - London dispersion forces is greater in substances with heavier atomic weight so greater energy is needed to separate the atoms of Xe than Ne.

13. Which is more viscous between glycerol and water based on their LEDES and intermolecular forces?



Glycerol



Water

- a. Glycerol because it has more OH⁻ groups that form London dispersion forces among the molecules.
 - b. Glycerol because it has more OH⁻ groups that form H-bonding among the molecules.
 - c. Glycerol because it has less OH⁻ groups that form London dispersion forces among the molecules.
 - d. Glycerol because it has less OH⁻ groups that form H-bonding forces among the molecules.
14. When does vapour pressure equilibrium happen?
- a. When the vapour pressure is equal to atmospheric pressure.
 - b. When evaporation occurs at the same time with condensation.
 - c. When the rate of vaporization is equal to the rate of condensation.
 - d. When the amount of vapour inside the container is equal to the amount of the liquid.
15. Which is true of vapour pressure?
- a. It is affected by the surface area of the liquid or solid.
 - b. Vapour pressure is higher when the temperature of the molecule is low.
 - c. Molecules with high molar heat of vaporization has low vapour pressure.
 - d. When vapour pressure is lower than atmospheric pressure, boiling occurs.

Lesson 1

Effects of Intermolecular Forces on the Properties of Substances

The properties of matter can be seen from either the microscopic or macroscopic level. The microscopic level includes the atoms, molecules, and ions which we cannot see. The macroscopic level shows how the bulk properties are exhibited by matter. These properties include surface tension, viscosity, boiling, melting, and freezing points, and solubility. Intermolecular forces play a very important role to determine how substances behave at the macroscopic level.

In this lesson, you will learn how the different forces of attraction bring about the bulk properties exhibited by substances. This lesson will help you understand why a certain substance behaves differently from other substances.



What's In

This simple activity will help you recall what you understood about the types of intermolecular forces present in each substance.



Notes to the Teacher

1. This module will help the students remember the concepts of intermolecular forces (IMF) and the forces of attraction present among species.
2. Allow the students to answer each part thoroughly, either individually or in pairs.
3. Let the students check the answers to each part. Have a short discussion of the concepts involved after checking.
4. The students will then move to the next part of the module. They will have the feedback and discussion after every part.
5. Inputs can be given in addition to the discussion in this module.
6. Kindly entertain questions for further discussions.

Directions:

1. Use a clean sheet of paper to answer this part.
2. Copy the table and fill it up with the correct information.
3. Show the direction of the dipole moment for each molecule.

Intermolecular Forces Present in Substances

Substance	LEDS	Shape	Polarity	Intermolecular Forces Present
1) CH ₃ OH				
2) O ₃				
3) CH ₃ NH ₂				
4) I ₂				
5) HF				



What's New

Activity 1:

Factors affecting the strength of intermolecular forces among molecules

Refer to the pairs of substances to answer the questions that follow.

- NaCl (sodium chloride) and CH_4 (methane)
 - CCl_4 (carbon tetrachloride) and CHCl_3 (trichloromethane or chloroform)
 - NH_3 (ammonia) and CH_3F (methyl fluoride)
 - PCl_5 (phosphorus pentachloride) and PBr_5 (phosphorus pentabromide)
 - C_5H_{12} (pentane) and C_5H_{12} (isopentane)
 - F_2 (Fluorine) and Br_2 (Bromine)
- Identify the *intermolecular forces* present in the substances in each pair.
 - Which of the forces predominates in each substance?
 - Tell which between the substances has greater intermolecular forces.
 - Predict which substance in each pair will have higher boiling and melting points.

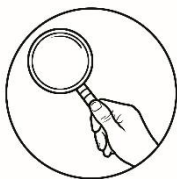
Activity 2:

- Refer to the chart below on physical properties of matter. Answer the questions and relate the intermolecular forces present among the species to explain the different properties exhibited by the substances.

Melting and Boiling Points

Substance	Molar Mass, g/mol	Melting Point, K	Boiling Point, K
Fluorine (F_2)	38	53	85
Bromine (Br_2)	160	266	332
Astatine (At_2)	420	575	610

- Which substance has the highest melting and boiling points?
- What intermolecular forces of interactions are present in each of the substances?
- How do the intermolecular forces present relate to the size of the substance?
- How do the strength of the intermolecular forces present in each species compare to each other?
- How does the strength of the intermolecular forces relate to the boiling and melting points of the substances?



What is It

This section gives brief and thorough explanation on how intermolecular forces affect the bulk properties of matter, namely surface tension, viscosity, boiling, melting, and freezing points, and solubility.

Activity 1:

The properties of substances as viewed on the macroscopic level can be explained by the types of intermolecular forces present between and among substances. These bulk properties can be predicted through an analysis of the interplay of intermolecular forces in each substance.

The chart below tells us of the relative strengths of intermolecular forces. This can be referred to when trying to relate the IMF to the properties of substances.

Relative Strengths of Intermolecular Forces

Ion-dipole	Strongest
H-bonding	
Dipole-dipole	
Dipole-induced dipole	
London dispersion forces	Weakest

Properties of substances affected by intermolecular forces

- Surface Tension

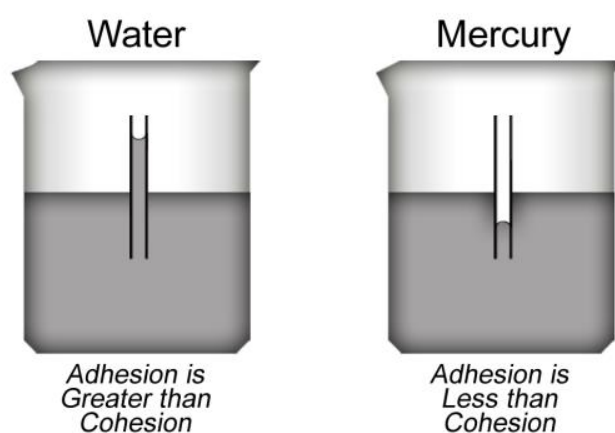
This is the amount of energy required to stretch the surface area of liquids (e.g., 1 cm²). Liquids with high intermolecular forces tend to have high surface tensions. When water is dropped on a waxy surface, it tends to form a round bead to minimize the surface area that it occupies.

An example of surface tension is capillary action. It is the ability of liquid molecules to move against gravity. The forces bringing about capillary action are cohesion (intermolecular attraction between like molecules) and adhesion (an attraction between unlike molecules).

Water molecules exhibit cohesion while the attraction between water and the sides of the glass tube is adhesion. If adhesion is stronger than cohesion, the liquid is pulled upward.

If cohesion is greater than adhesion, there is a depression or lowering, resulting to a lower height of the liquid in the capillary tube.

CAPILLARY ACTION IN

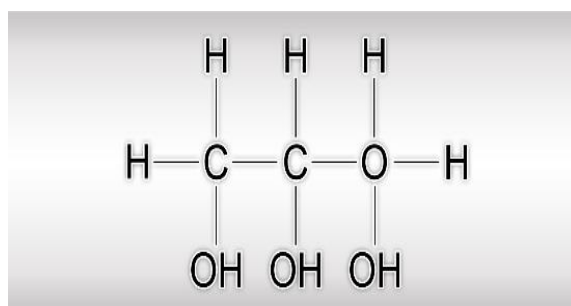


The stronger the intermolecular forces possessed by molecules, the higher is the surface tension of the substance.

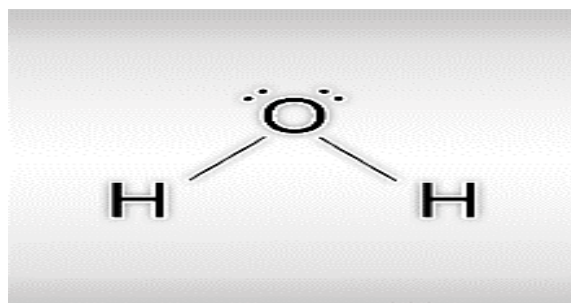
- Viscosity

This is a measure of a liquid's resistance to flow. The greater the viscosity of a liquid, the more slowly it flows. The viscosity of substances decreases with high temperatures; thus, syrup flows faster when hot.

The strength of intermolecular forces affects the ease with which substances flow. Liquids that have high intermolecular forces are highly viscous. The presence of strong H-bonds in some liquids makes these substances highly viscous. The LEDES of glycerol below shows three (3) OH⁻ groups that can participate in H-bonding whereas water has only one OH⁻ group to form H-bonding. Glycerol is more viscous than water.



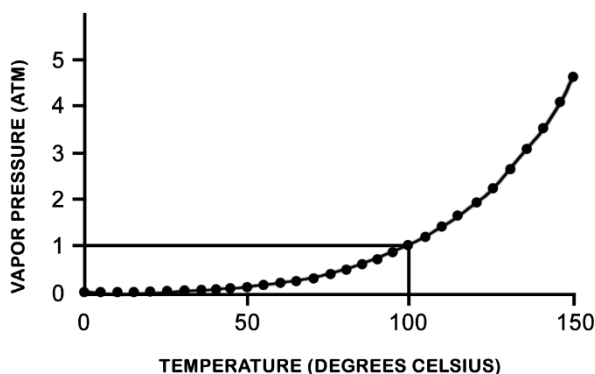
Glycerol



Water

- Boiling Point and Melting Point

Boiling point depends on the equilibrium vapour pressure exerted by the liquid or solid above the liquid or the solid. This means that the rate of vaporization is equal to the rate of condensation of the substance in a closed container. Vapour pressure also varies with temperature. The graph below shows the effect of temperature on the vapour pressure of water.



Source: <https://www.chem.purdue.edu/gchelp/liquids/vpress.html>

At 100°C, the vapour pressure is equal to the atmospheric pressure of 1.00 atm. Boiling occurs at this point, where the vapour pressure of water is equal to the pressure of the atmosphere.

There are substances that boil at a lower temperature and some at a higher temperature. These temperatures depend on the vapour pressure exerted by the liquids or solids. Vapour pressure, on the other hand, depends on the intermolecular forces present in the substances. When the intermolecular forces are strong, the vapour pressure is low.

As a consequence, boiling will occur at a higher temperature because more energy is needed to break the intermolecular bonds for the substance to change into vapour. Water, for example, exhibits strong H-bonds such that vaporization needs more energy to change the liquid to vapour.

London dispersion forces predominate in methane, CH₄. These are the weakest forces of attraction among molecules. It needs a little energy to break the bonds such that methane changes to vapour easily. As a consequence, more vapour are released in which vapour pressure will eventually equal to atmospheric pressure. Boiling then will occur. This explains why water has a higher boiling point than methane.

This condition is also true for melting point. The ease with which bond breaks affects the melting points of substances. The greater intermolecular forces there are among molecules the higher is their melting point.

The strength of dispersion forces also depends on the size of the substance or the number of electrons in the substances. The ease with which the electron distribution is distorted explains the amount of dispersion forces that a substance exhibits. The distortion of the electron distribution is known as polarizability.

The greater the polarizability of the electron distribution the greater are the dispersion forces. When the dispersion forces are high, the boiling and melting points are also high.

Br₂ and F₂ are both diatomic gases. They are also both nonpolar, but Br₂ is a bigger molecule than F₂. The polarizability of Br₂ is greater than F₂ so it has greater dispersion forces. This explains why Br₂ has a higher boiling point than F₂. Greater amount of energy is needed to overcome the big dispersion forces in Br₂ than in F₂.

- Solubility

Solubility is the ability of a substance (solid, liquid, or gas) to dissolve in a given substance (solid, liquid, or gas). The amount of any substance dissolved in a solvent (the substance that dissolves another substance) depends on the types of interaction among molecules, pressure, and temperature.

The rule “Like dissolves like” applies to solubility. This means that the kind of substances being dissolved should exhibit the same properties or should be compatible for them to form solutions. The polarity of molecules is an important factor for substances to dissolve in certain molecules. Highly polar molecules will dissolve substances that have dipoles. The negatively-charged particles will be attracted to the positively-charged particles of the involved substances. This attraction will subsist in the solutions.

Water is considered as a universal solvent because of its ability to dissolve almost everything. Water is highly polar and has the ability to form H-bonds with polar substances.

Nonpolar substances, on the other hand will also dissolve nonpolar substances. Intermolecular forces, such as dispersion forces, will prevail to maintain the dissolution of substances.

To predict the behaviour of substances, several considerations should be taken.

First, the polarity of substances should be determined together with the predominant intermolecular forces present in the substances. For example, consider NaCl (sodium chloride) and CH₄ (methane). NaCl is a dipole while methane is nonpolar. Dipole-dipole interaction is predominant in NaCl while dispersion forces are present among methane molecules.

Since dipole-dipole forces are stronger than dispersion forces, NaCl will have higher boiling and melting points. It is also highly soluble in water due to ion-dipole interaction that will prevail. Methane is not soluble in water because there are no poles that will participate in the dissolution process with water.

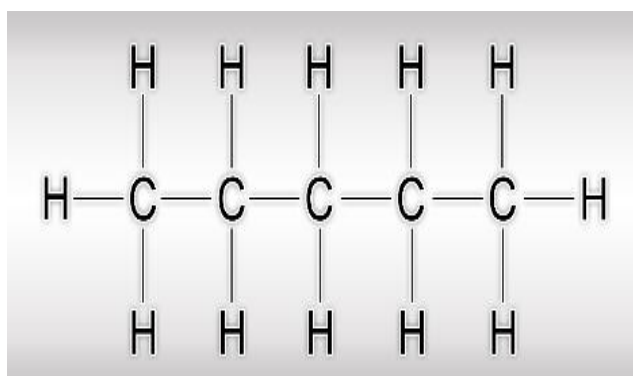
Between CCl₄ (carbon tetrachloride) and CHCl₃ (trichloromethane), trichloromethane has a higher boiling and melting points than carbon tetrachloride. It is also slightly soluble in water. Trichloromethane is a polar molecule while carbon tetrachloride is a nonpolar molecule. The dipole-dipole interaction in CHCl₃ is stronger than the dispersion forces in CCl₄. Again the boiling and melting points are higher in CHCl₃ than in CCl₄. Hence, since CHCl₃ is polar, then it is soluble in water.

Ammonia (NH₃) and methyl fluoride (CH₃F) are both polar but the ability of NH₃ to form H-bonds qualifies it for higher boiling and melting points than CH₃F. At the same time, H-bonding also enables NH₃ to be more soluble in water than CH₃F.

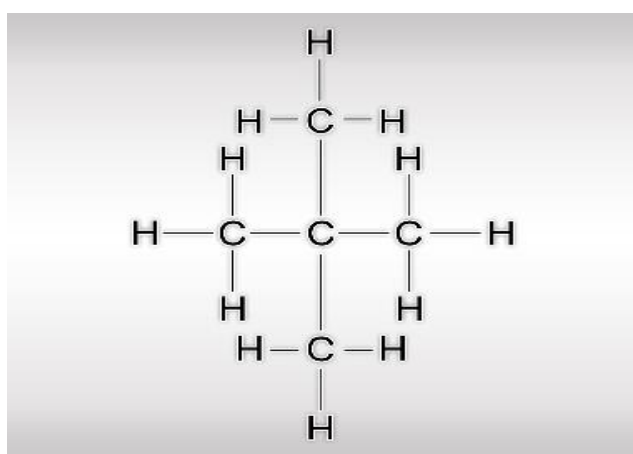
Phosphorus pentachloride (PCl₅) and phosphorus pentabromide (PBr₅) have the same molecular shape and polarity. What matters here is the size of the molecule when comparing the properties of these substances. Bromine contains more electrons than chlorine. This makes PBr₅ bigger and heavier. In this case, dispersion forces are greater in PBr₅ so it has higher boiling and melting points than PCl₅. Since these two substances are both nonpolar, then they are not soluble in water.

Pentane (C_5H_{12}) and isopentane (C_5H_{12}) both contain the same number of C and H atoms in the formula. However, their molecular structures are different. Below are the LEDS of the two substances.

Pentane has an extended structure while isopentane has a compact structure. Extended structures have more opportunities for interactions than compact structures. Extended molecules have stronger intermolecular forces than the compact structures. As such the boiling point of pentane is higher than that of isopentane. It is also true for their melting points. Both molecules are nonpolar so they are not soluble in water.

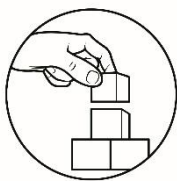


Pentane



Isopentane

The nature of intermolecular forces present in molecules is a good gauge to predict properties of substances.

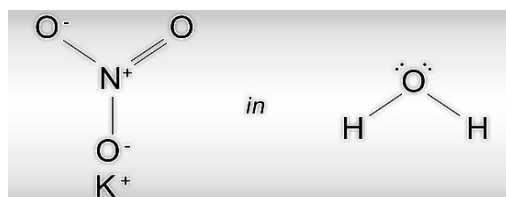


What's More

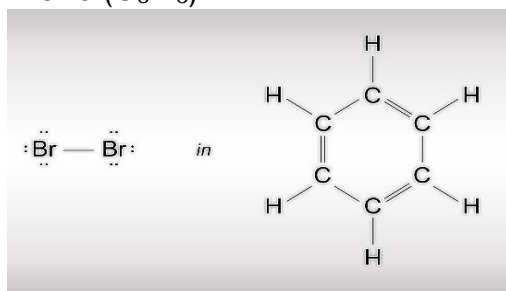
Activity 1.1

1. Identify the principal type of solute-solvent interaction responsible for forming the following solutions:

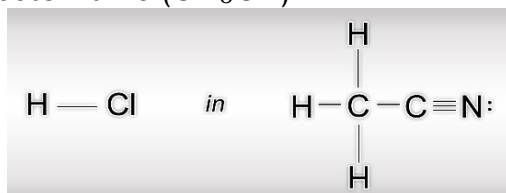
a. KNO_3 in H_2O



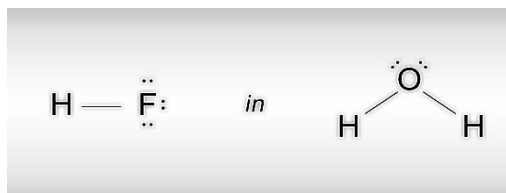
b. Br_2 in benzene (C_6H_6)



c. HCl in acetonitrile (CH_3CN)

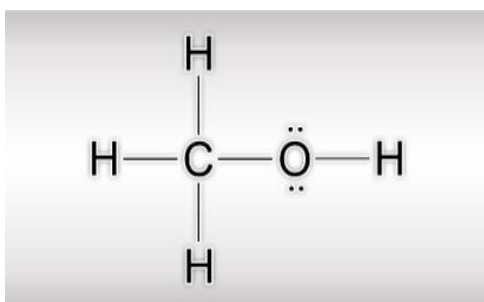


d. HF in H_2O

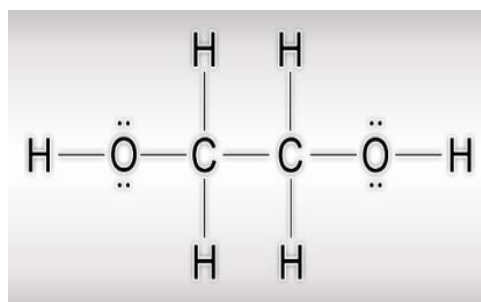


2. Which pair/s of substances will dissolve in each other?
- CH_3NH_2 and H_2O
 - $\text{CH}_3\text{-CH}_3$ and CH_3OH
 - SO_2 and CH_4
 - MgCl_2 and H_2O
 - $\text{CH}_2 = \text{CH}_2$ and CH_4
3. Arrange the following substances in the order of increasing boiling points.

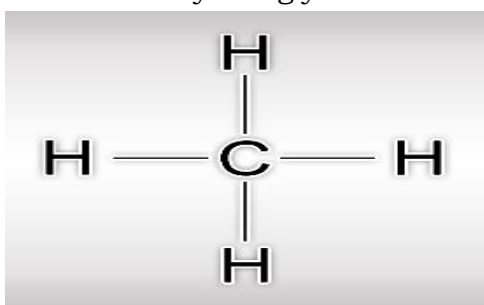
a. Ethanol



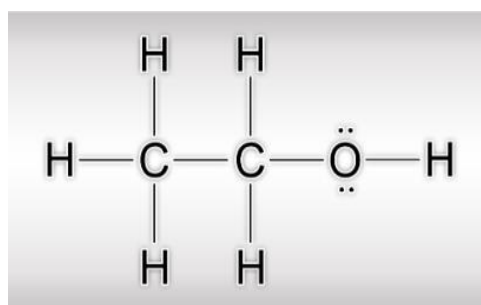
b. Ethane



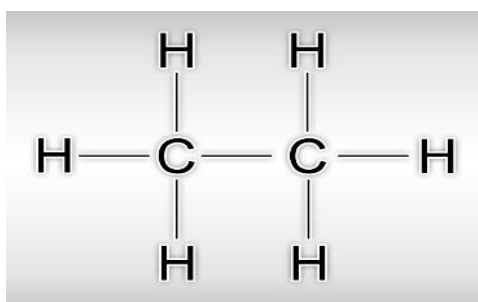
c. Ethylene glycol



d. Methane



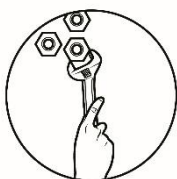
e. Methanol





What Have I Learned

1. What are the properties of matter influenced by intermolecular forces?
2. Rank the intermolecular forces in the order of increasing strengths.
3. What steps or considerations do we take to determine the effects of intermolecular forces on the properties of matter?

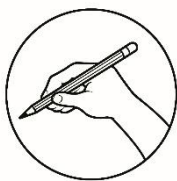


What I Can Do

Knowledge of concepts is not enough for a learning experience to be meaningful. We should also understand how the concepts we learned on intermolecular forces can be applied to real life situations to get the most out of what we learned. Let us look at this simple situation that will help us realize the advantage of fully understanding intermolecular concepts.

Situation:

You are asked by your mother to cook pork nilaga. You have only an ordinary kettle to use for cooking. She even reminds you to save energy because we are in a state of pandemic due to covid-19. Saving resources nowadays is a must because we are not sure of the world's economy. As a student of Physical Science and with your knowledge of properties of matter in relation to intermolecular forces, how are you going to perform your task in such a way that energy is not wasted?



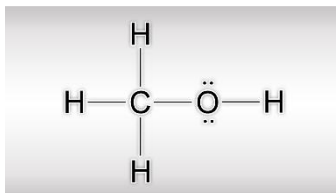
Assessment

Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

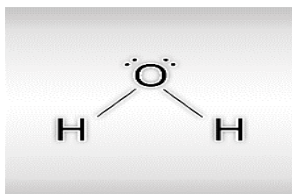
1. The properties of matter seen in the macroscopic level influenced by intermolecular forces
 - a. bulk
 - b. ionic
 - c. covalent
 - d. individual
2. Which intermolecular forces depend on the polarizability of molecules
 - a. ion-dipole
 - b. dipole-dipole
 - c. Hydrogen bonding
 - d. London dispersion forces
3. Cohesive forces bring about capillary action. These forces are
 - a. pulling molecules towards gravity.
 - b. interactions among polar molecules.
 - c. attractions among different molecules.
 - d. drawing together of the same kind of molecules.
4. When adhesion is stronger than cohesion, the liquid is pulled
 - a. upward and results to concave meniscus.
 - b. downward and results to convex meniscus.
 - c. upward and becomes higher than the surrounding liquid.
 - d. downward and becomes higher than the surrounding liquid.
5. What is true of viscosity of substances?
 - a. Viscosity of substances increases as the temperature increases.
 - b. The least viscous substance flow the slowest among the substances.
 - c. Molecules that form H-bonds have higher viscosities than those with London dispersion forces.
 - d. Substances with London dispersion forces exhibit greater viscosity than those with ion-dipole interactions.

6. When intermolecular forces are high, the boiling point is expected to be
- low.
 - high.
 - dependent on the kinds of atoms.
 - dependent on the number of atoms.
8. Water is a polar molecule that is capable of forming H-bonds. What is expected of its vapour pressure?
- It is low since weak intermolecular forces are present.
 - The polar ends hinder the breaking of bonds, thus less water vapour is produced.
 - Vapour pressure is high since great amount of energy is needed to break the H-bond.
 - Vapour pressure is low since it is hard to break the H-bond among the molecules and escape as vapour.
9. Which intermolecular forces among the following allows for easy escape of molecule to the vapour phase?
- H-bonding
 - ion-dipole forces
 - dipole-dipole interaction
 - London dispersion forces
10. The vapour pressure on top of the mountain is low so what will happen to the cooking time of an egg up there?
- The cooking time will be longer since the temperature of the water is higher.
 - The cooking time will be shorter since the temperature of the water is higher.
 - The cooking time will be longer since the temperature of the water is lower.
 - The cooking time will be shorter since the temperature of the water is lower.
11. Methane will not dissolve in water due to
- greater molar mass of H_2O than CH_4 .
 - the same intermolecular forces they possess.
 - difference in the kinds of atoms in their structure.
 - difference in intermolecular forces between the two substances.

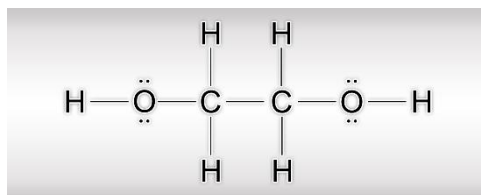
12. Which among the following substances has lower viscosity than methyl alcohol?



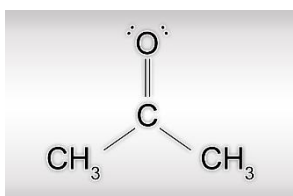
a. Water, H_2O



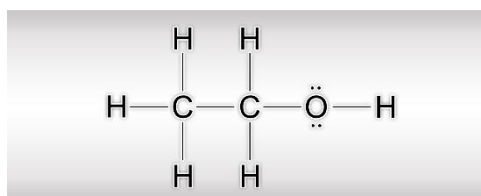
b. Ethylene glycol



c. acetone



d. ethyl alcohol



13. Arrange in increasing boiling points.

I. CO_2

II. H_2O

III. O_2

IV. $\text{C}_6\text{H}_{12}\text{O}_6$

- I, II, III, IV
- III, I, II, IV
- III, II, I, IV
- II, I, IV, III

Identify the predominant intermolecular forces present between each pair of molecule.

14. Water (H_2O) and acetic acid (CH_3COOH)

15. Carbon dioxide (CO_2) and methane (CH_4)

15. Potassium iodide (KI) and Water (H_2O)

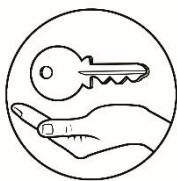


Additional Activities

This part will test whether you fully understand the influences of intermolecular forces present between and among species to the bulk properties of substances. You can answer this by recalling the strategies discussed earlier in this module. Remember also that the predominant intermolecular forces are the determinants of what the bulk properties of substances will be.

Explain the differences in boiling point in terms of intermolecular forces (IMF).

- a. HF (20° C) and HCl (-85° C)
- b. CHCl₃ (61° C) and CHBr₃ (150° C)
- c. Br₂ (59° C) and ICl (97° C)

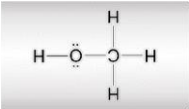
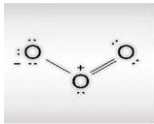
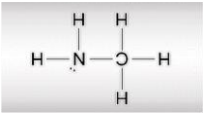
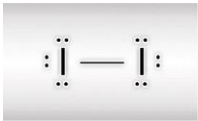



Answer Key

<p>What I Know</p> <p>1. A 2. B 3. D 4. A 5. D 6. A 7. A 8. D 9. B 10. C 11. B 12. D 13. B 14. C 15. C</p>	<p>What's More</p> <p>1. a) ion-dipole forces b) London dispersion forces c) dipole-dipole forces d) H-bonding e) Soluble</p> <p>2. a) Soluble b) Insoluble c) Insoluble d) Soluble e) Soluble</p> <p>3. Methane < Ethane < Methanol < Ethanol < Ethylene glycol</p>	<p>Assessment</p> <p>1. A 2. D 3. D 4. C 5. C 6. B 7. D 8. D 9. C 10. D 11. C 12. B 13. H-bonding forces 14. London dispersion forces 15. Ion-dipole forces</p>
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What's In

Intermolecular Forces Present in Substances

Substance	LEDS	Shape	Polarity	Intermolecular Forces Present
1. CH_3OH (Methyl alcohol)		Tetrahedral, bent	Polar	H-bonding, London dispersion forces, dipole-dipole interaction
2. O_3 (Ozone)		Bent	Polar	London dispersion forces, dipole-dipole interaction
3. CH_3NH_2 (Methyl amine)		Tetrahedral, bent	Polar	H-bonding, London dispersion forces, dipole-dipole interaction
4. I_2 (Iodine)		Linear	Nonpolar	London dispersion forces
5. HF		Linear	Polar	H-bonding, London dispersion forces, dipole-dipole interaction

What's New

Act. 1

1. a. NaCl : dipole-dipole, London dispersion forces
 b. CCl₄ : London dispersion forces; CHCl₃ : dipole-dipole, London dispersion forces
 c. NH₃ : dipole-dipole, H-bonding, London dispersion forces ; CH₃F : dipole-dipole, London dispersion forces
 d. PCl₅ : London dispersion forces; PBr₅ : London dispersion forces
 e. Pentane (C₅H₁₂ (pentane) : London dispersion forces
 f. F₂ (Fluorine) : London dispersion forces; Br₂ (Bromine) : London dispersion forces
 2. a. NaCl : dipole-dipole; CH₄ : London dispersion forces
 b. CCl₄ : London dispersion forces; CHCl₃ : dipole-dipole
 c. NH₃ : H-bonding ; CH₃F : dipole-dipole
 d. PCl₅ : London dispersion forces; PBr₅ : London dispersion forces
 e. C₅H₁₂ (pentane) : London dispersion forces
 f. F₂ (Fluorine) : London dispersion forces; Br₂ (Bromine) : London dispersion forces
 3. a. NaCl
 b. CHCl₃
 c. NH₃
 d. PBr₅
 e. C₅H₁₂ (pentane)
 f. Br₂ (Bromine)
 4. a. NaCl
 b. CHCl₃
 c. NH₃
 d. PBr₅
 e. C₅H₁₂ (pentane)
 f. Br₂ (Bromine)
- Activity 2
1. a. Astatine has the highest melting and boiling points.
 b. F₂ – London dispersion forces; Br₂ – London dispersion forces;
 At₂ – London dispersion forces
 c. Intermolecular forces vary with the size of the molecule. The greater the size of the molecule the greater are the intermolecular forces among the molecules.
 d. F₂ < Br₂ < At₂
 e. The greater the intermolecular forces, the higher the boiling and melting points of the substances.

What Have I Learned

1. The properties influenced by intermolecular forces are surface tension, viscosity, boiling, melting, and freezing points.
2. $\text{LDF} < \text{dipole-induced dipole} < \text{dipole} - \text{dipole} < \text{H-bonding} < \text{ion} - \text{dipole}$
3. Steps or considerations to take to determine the effects of IMF to the properties of matter.
 - a. Determine first whether the substance is polar or nonpolar.
 - b. If the substance is polar, then dipole-dipole forces are present. If the substance has H attached to O, N, F, then H-bonding can also form. London dispersion forces are always present in all substances.
 - c. If the substance is nonpolar, then London dispersion forces are the predominant intermolecular forces among the molecules.
 - d. If the substance is ionic then ion-dipole forces of attraction will prevail.
 - e. Determine the polarity of substances with the same number of atoms and molecular geometry. If they are identical, then the mass of the molecule will tell which between the two substances has greater intermolecular forces.
 - f. Determination whether the structure of the molecule is extended or compact will also tell which one has the greater intermolecular forces.
 - g. The strength of the predominating intermolecular forces will be the gauge for predicting the physical properties of matter.
 - h. Remember that greater IMF will result to higher boiling, melting, and freezing points. Solubility will depend on the type of molecules. "Like dissolve likes" is the rule in the dissolution process.

Additional Activities

- a. The prevailing IMF in HF is H-bonding while in HCl is dipole-dipole forces. H-bonding is stronger than dipole-dipole interactions so greater amount of energy is needed to break the bonds of HF than the bonds in HCl. This results to higher boiling point of HF.
- b. Both have dipole-dipole and London dispersion forces of attraction. Thus, the basis will be the masses of the molecules. Since the mass of CHBr_3 is greater than the mass of CHCl_3 , then the London dispersion forces is greater than in CHCl_3 . It needs greater amount of energy to break the bonds in CHBr_3 than in CHCl_3 , thus CHBr_3 has a higher boiling point than CHCl_3 .
- c. Br_2 is nonpolar while ICl is polar. London dispersion forces prevail in Br_2 while dipole-dipole forces in ICl . It's harder to break the dipole-dipole bonds than LDF so more energy is required to break the bonds resulting to higher boiling point of ICl .

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